Status report on the DarkSide-50 WIMP search project

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DarkSide-50 is a direct detection dark matter experiment currently under construction at LNGS, that features a two phase depleted liquid argon time projection chamber (LAr-TPC) with an active volume of 50 kg liquid argon. A selection of low background materials and active background suppression will give the DarkSide-50 the capability to measure its low backgrounds in-situ thereby allowing for a background-free search of WIMP interactions in the TPC with a projected sensitivity of $\sigma_{spin-indep.} = 1 \cdot 10^{-45}$ cm^2, after 3 years of operation and at a WIMP mass of 100 GeV/c^2. DarkSide-50 is part of the DarkSide program, which provides R&D for the next generation LAr-TPC with a ton-scale fiducial volume.

1 Introduction

There is wide ranging evidence from various independent astrophysical and cosmological sources that the universe consists of ~ 26 % dark matter [2]. While the nature of dark matter is as yet unknown, weakly interacting massive particles (WIMPs) as they arise in supersymmetric theories are possible dark matter candidates [3].

2 DarkSide-50

The DarkSide-50 experiment (DS-50) aims to directly detect WIMP interactions using a two-phase liquid argon TPC (LAr-TPC).

A particle interacting in the argon excites argon molecules and argon dimers form temporarily in a singlet or triplet state. Argon scintillation light stems from the deexcitation of these dimers. The scintillation light is observed with photo multiplier tube (PMT) arrays on top and bottom of the TPC (Fig. 1).

The singlet state deexcites with a time constant of ~ 5 ns, while the triplet state deexcites with a time constant of ~ 1500 ns. The relative population of the singlet and triplet depends strongly on the ionization density and therefore can be used for particle identification via pulse shape discrimination (PSD). The excellent light yield of the argon scintillator is benefitial for PSD and has been measured as ~ 9 P.E./keV$_{ee}$ in the DS-10 prototype [5].

The argon TPC is operated in two phases, which gives two signals per interaction (Fig. 1): a primary scintillation signal (S1) proportional to the deposited energy and a secondary signal

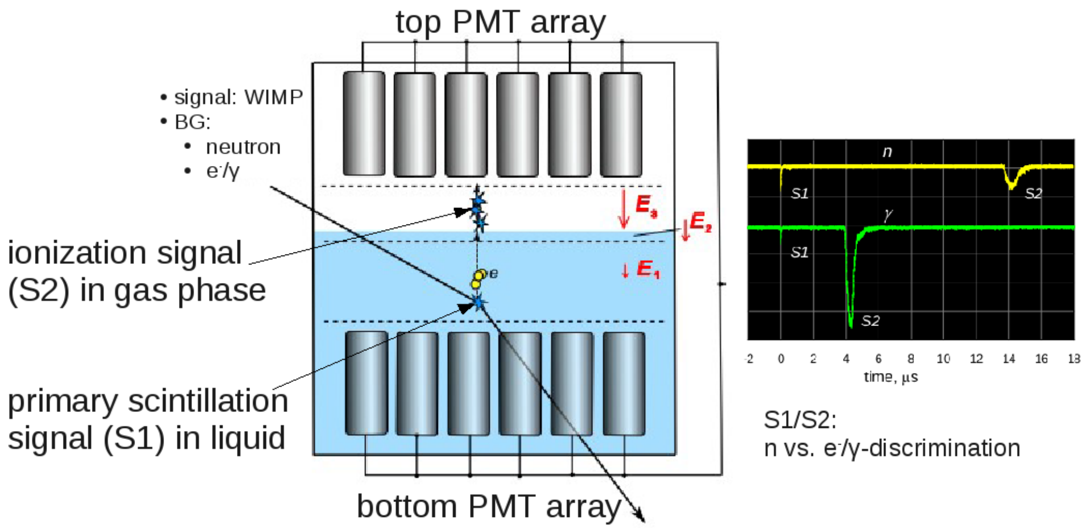

Figure 1: Schematics of the two phase liquid argon TPC (adapted from [4]).

(S2) proportional to the ionization charge, that is being released during the primary particle interaction. Also the ratio of S1/S2 is particle dependent and allows for a discrimination of β/γ events versus neutrons and WIMP candidates. The vertex of the interaction can be reconstructed with sub-centimeter precision in the XY-plane and sub-millimeter precision in Z, which allows for the identification of single- vs. multi-site events and the effective rejection of surface events (fiducialisation).

^{39}Ar depleted argon

Despite its attractivity as detector medium, a LAr-TPC is affected adversely by ^{39}Ar, which is present in atmospheric argon at a rate of 1 Bq/kg (β-emitter, Q=565 keV, $t_{1/2}$ = 269 years) [6]. This causes pile-up problems, when the active volume of the argon TPC is increased to the ton-scale. For DS-50 underground argon will be used, which is depleted of ^{39}Ar by at least a factor of 100 [6].

3 Background avoidance, measurement and rejection

In order to minimize backgrounds in the first place, detector components and construction materials have been systematically screened and selected for low background rates. To reduce muon induced backgrounds the detector is placed underground in the LNGS hall C. Further reduction is achieved by having the TPC's cryostat in the middle of a stainless steel sphere of 4 m diameter filled with borated liquid scintillator (Fig. 2). This so called neutron veto is in turn surrounded by a 1kt water Cerenkov veto, which is the former Borexino CTF tank. The 4π coverage of the TPC with the neutron veto alone allows to reduce cosmogenic neutrons by a factor of 20 [7].

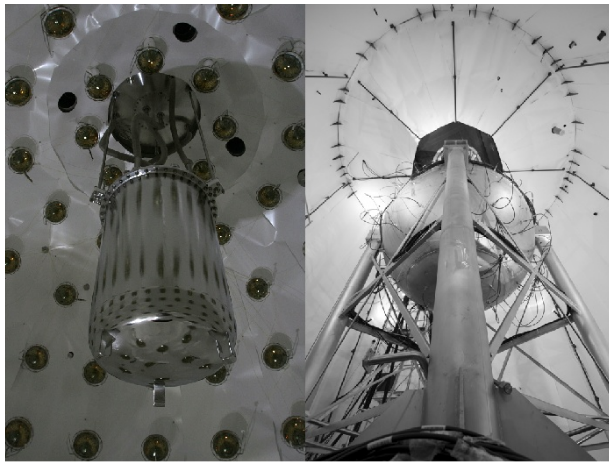

Figure 2: The cryostat of the TPC in the neutron veto, june 2013 (left), the liquid scintillator neutron veto in the CTF tank (right).

Neutron veto

Radiogenic neutrons originating from spontaneous fission and (α,n)-reactions in the TPC, the PMTs or the cryostat form an important class of backrounds. A fraction of these neutrons leaves a signal in the TPC, which is indistinguishable from WIMP interactions: neutrons that interact once in the TPC and then leave the TPC. Dedicated MC studies have shown, that this dangerous class of background can be detected and rejected in the borated liquid scintillator surrounding the cryostat with very high efficiency ($\leq$ 99 %) [7]. The high efficiency of the boron against neutron backgrounds comes from the high capture cross section of thermal neutrons and the release of an alpha rather than an energetic gamma, which cannot escape the detection volume, due to its small mean free path length.

In summary, the DS-50 employs a multi-facetted strategy against the numerous backgrounds of a direct WIMP search: Screening for low background material and components, passive shielding, and active rejection methods: pulse shape discrimination, fiducialisation, S1/S2 discrimination, and *in-situ* measurement of remaining backgrounds, in particular radiogenic neutron backgrounds through neutron veto/ TPC coincidences. This will enable the DS-50 experiment to run practically background free for several years.

4 Construction and Commissioning

As of June 2013 the 1kt water Cerenkov veto in the CTF is covered with Tyvek reflective foil and PMT installation is imminent (Fig. 2, right). The inside of the neutron veto sphere is covered by lumirror reflective foil and all 110 8$''$ PMTs are installed, tested and commissioned (Fig. 2, left). The neutron veto is ready for filling of the borated liquid scintillator, which is scheduled for fall 2013. The liquid argon TPC has been assembled successfully in the radon-free clean room (CRH) and installed in the cryostat.The cryostat has been lowered into the veto (Fig. 2, left).

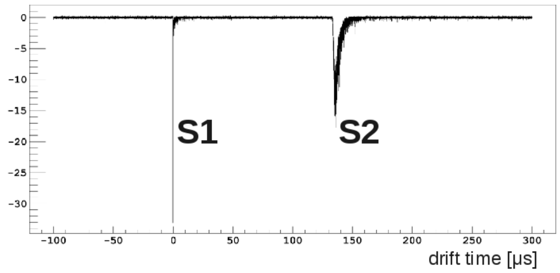

Figure 3: First light in the DS-50 TPC with a gas pocket, showing a primary scintillation signal (S1) followed by an ionization signal (S2).

The TPC has been filled successfully with *atmospheric* argon using the Argon circulation and purification system in May 2013 and has been commissioned in the weeks after. Basic functionals tests and first measurements of physics parameters of the TPC have been made and calibration runs have been taken. A gas pocket was successfully established and first S1/S2 signals were observed (Fig. 3). Until including July 2013 commissioning data has been taken to determine basic and essential physics parameters, such as the electron lifetime, PMT gains, the light yield. This includes calibration runs using ^{137}Cs and ^{85}Kr. All of these data are being used to establish the functionality of the LAr-TPC as well as tuning of the Monte Carlo.

5 Summary & Outlook

After the successfull TPC commissioning, several major operations are being undertaken in Fall 2013. The TPC is being refilled with *underground argon* and the neutron veto is being filled for the first time with borated liquid scintillator, soon after followed by the filling of the water veto, after which first data taking runs in the final detector (and shielding) configuration will be taken.

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